Out-of-Field Physics Teaching in Urban, Suburban, and Rural Contexts

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Abstract

This observational study focused on the content preparation of physics teachers in an analysis of certification level (primary vs. secondary), in addition to in-field vs. out-of-field certification status. The sample included public-school physics teachers (n=1387) in New York State in the academic year 2011-12. A case study of New York is useful since teacher certification policy is largely determined at the state level in the United States. Data were collected from a variety of publicly available sources, and included information about the teachers' primary and secondary certifications, the courses they taught, the locales and socioeconomic status of their schools, student performance on chemistry and physics standardized exams, and the extent of out-of-field teaching that occurred. Findings indicated that overall the number of teachers teaching physics out-of-certification was relatively low, but this masked large disparities when considering locale and socioeconomic status, with suburban and rural schools having very few out-of-field teachers, while in urban and high need schools they were much more prevalent. Multivariable regression analyses indicated students of out-of-field physics teachers did not perform as well as students of certified teachers, however, student performance was not related to whether or not teachers had primary certification (the equivalent of a degree) or secondary certification (minimum number of credits) in their field. In both cases, school-level socioeconomic status was the main predictor of student performance. Implications related to equity considerations and science teacher certification policy are discussed.

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SUBJECT/PROBLEM

The preparation of science teachers has been the focus of debate regarding subject-specific coursetaking and certification. Throughout the U.S., in order to earn teaching certification, candidates are generally required to complete a bachelor's degree with a major in the area of certification, pedagogy classes, and a sequence of examinations. These requirements, plus student teaching, are typically addressed through completion of a college-based program that has been approved by the state and a national accrediting agency (Imig & Imig, 2008). However, researchers have found that certain teacher credentials do not always correlate to teacher quality in terms of student achievement (Angrist & Guryan, 2008), and the effects of teacher quality are often confounded by school demographics such as socioeconomic status and racial composition (Clotfelter et al., 2010). The present study focuses on the content preparation of physics teachers in an analysis of certification level (primary vs. secondary), in addition to in-field vs. out-of-field certification status. Although some studies have explored national and international educational trends while acknowledging both the localized nature of decision making and globalization forces (Olson et al., 2015), we argue that state-specific case studies have an increased potential for identifying contextual impacts of state mandated licensure due to the persistent fragmented nature of U.S. professional education standards.

Many science teachers, particularly in physics, do not have degrees in the disciplines they teach (White & Tyler, 2015). School administrators often have difficulty distributing teaching assignments in their science departments, especially when attempting to arrange for teachers to teach courses in their primary certification area (Darling-Hammond & Berry, 2006). Furthermore, teachers with strong credentials are typically unevenly distributed among schools with varying socioeconomic status, potentially contributing to the achievement gap (Clotfelter et al., 2010). In response to science teacher shortages or the need for within-school

flexibility in staffing assignments, states often offer teachers the opportunity to earn teaching licenses in *secondary* science disciplines after accumulating a specific number of credits in that field. The present study explored the incidence and distribution of out-of-field teaching through the investigation of the primary and secondary certifications of public school physics teachers in New York State. This state context was chosen because of the robust, transparent system of data reporting and the long-term prevalence of state standardized science exams at the high school level. The study further considers some of the impacts that the distribution of teacher certifications had on issues concerning student accessibility, enrollment, and performance in chemistry and physics. The research questions included the following:

1. What are the certification trends and prevalence of out-of-field teaching of public-school physics teachers in a case study of New York State? How do these trends vary across urban, suburban and rural locales?
2. How do physics access and course-taking patterns for students vary among these locales?
3. What is the predictive value of physics certification type, in-field vs. out-of-field certification status, and school-level socioeconomic status with regard to student physics performance?

Theoretical framework. The theoretical framework for the present study is based upon Chi, Glaser, and Rees's proposed theory regarding domain specific knowledge as the core determinant of science and science teaching expertise. Knowledge base differences often account for varying performance levels and procedural skill development among science educators. Physics teachers with extensive content knowledge, for example, apply physical intuition in constructing physical representations and articulating problem-solving processes to novices (Etkina, 2010). This is particularly important in sciences with symbol-laden problem-solving schemes (Chi et al., 1982). Researchers have advanced this model in arguing for the importance of subject matter expertise in teaching science effectively (De Jong et al.,

2002). The present study considers the issue of teachers'? subject matter knowledge as evidenced by teachers' certification in physics, course accessibility, coursetaking patterns, and differential socioeconomic contexts.

DESIGN/PROCEDURE

***Research design*.** This is an observational study of public-school physics teachers (*n*=1387) in New York State in the academic year 2011-12. Data used in the study were taken from publicly available and verified state databases. The quantitative research methods employed in the study are part of a larger non-experimental correlational design (Shadish, Cook, & Campbell, 2002). The purpose was to identify the extent of physics teacher primary and secondary certification (including the extent and incidence of out-of-field teaching), as well as relationships among locale, socioeconomic status, student performance, and teacher certification type. Descriptive findings are presented and additional inferential tests were conducted. Multiple linear regression models were generated to determine whether certification status and socioeconomic status predicted student performance on state-wide standardized examinations in physics. In all multivariable regression models, collinearity diagnostics revealed variance inflation factors (VIF) between 1-2, indicating independence of the predictor variables.

***Context*.** This study was conducted in New York State, which is the third most populous state in the country in terms of its K-12 student population. It has a general population approaching 20 million people with over three million students (2.7 million in public schools, 0.4 million in private schools). New York has a state-wide system of college preparatory courses that lead to examinations known as the Regents Examinations. As the state requires at least three years of science to graduate, students can complete either Regents chemistry or physics to meet their science graduation requirement (NYSED, 2019a).

Science teacher certification in New York State. New York State grants *single-field* certification in four fields of science – biology, chemistry, Earth science, and physics. Since 2004, to qualify for certification in a specific science, a candidate is required to complete a college major or its credit equivalent (minimally 30 credits) in the science subject of the certification and pass the Content Specialty Test (NYSED, 2017). The first science certification earned by teachers is their *primary* certification. Additional science certifications are *secondary* certifications. The key difference between primary and secondary certifications relates to college content credits. Primary certification was earned by completion of an approved program that required a sequence of content courses to complete a bachelor's degree. To earn a secondary certification, the teacher had to complete at least 30 *credits, equivalent to a major* (NYSED, 2017).

Data collection. The Teacher Certification database (TEACH) was used to individually determine the science teaching certifications of all physics teachers (NYSED, 2019b). The New York State *Basic Education Data System* database was used to determine the type and level of physics courses taught by each teacher, including college preparatory, AP, College, or Other. Locale codes for each school district were retrieved from the U.S. Department of Education publication *Documentation to the NCES Common Core of Data* (NCES, 2012). School locales were identified as urban, suburban, town, or rural. Suburban and town were collapsed into a single category due to contextual similarities. Overall, 1387 physics teachers were included in the study. Student performance data were reported as school-level percentage passing rates on physics state standardized exams (NYSED, 2013).

RESULTS/ANALYSIS

The analysis of out-of-field physics certification followed a three-tiered approach. First, the certifications of all physics teachers across the state were determined, as well as what specific courses they taught, the locales in which they taught, and the socioeconomic status of

their schools. Similar data were then obtained for the physics teachers who were considered to be teaching out-of-field, that is, teachers who did not hold a current valid state certification in physics. Secondly, data were obtained for the teachers with respect to their primary certification (i.e. whether they were teaching in their undergraduate major or equivalent). Descriptive statistics were generated in terms of; 1) in-field vs. out-of-field certification status, and 2) primary vs. secondary certification status. Finally, inferential models were tested to determine whether these classifications, when combined with school-level socioeconomic status, predicted student performance on a standardized physics examination.

Out-of-field teaching by physics certification. A relatively large percentage of physics teachers (82%) held physics certification, that is, they had at least a minor or its equivalent in physics; 4% of the 250 uncertified physics teachers held no science certification. The majority of uncertified physics teachers were certified in mathematics. Out-of-field physics teaching was also analyzed in terms of locale, school-level socioeconomic status, and courses taught (Table 1). Urban and high need schools were the categories with most out-of-field physics teachers. More than a quarter of all urban, rural, and high need school teachers did not hold physics certification. Suburban, average need, and low need schools by comparison had relatively low proportions of non-certified teachers. When examining out-of-field teaching with respect to the courses taught, data indicated that courses that led to external examinations (college preparatory, AP, and college courses) were largely taught by certified physics teachers (83%). The relatively higher numbers of uncertified physics teachers in college preparatory physics was a condition of mainly the rural and urban schools. Notably, AP courses were predominantly taught by certified subject teachers.

Table 1. *Out-of-Field Physics Teachers by Locale, Socioeconomic Status, and Course, 2011-12*

Teachers Out-of-Field by Locale (% in category)	*Rural*	78 (27%)
	Suburban/Town	73 (10%)
	Urban	99 (27%)
Teachers Out-of-Field by Socioeconomic Status	*High need*	155 (29%)
	Average need	75 (14%)
	Low need	18 (6%)
Teachers Out-of-Field by Course	*College Preparatory*	173 (15%)
	AP & College	8 (2%)
	Other	73 (18%)

Primary and secondary certifications. Teachers with primary certification generally had a major (or equivalent) in the subject. In physics, 1137 of the 1387 physics teachers had physics certification (82%). More than half of the physics teachers (59%) held primary certification in physics, while one-third were primarily certified in other fields, mainly biology and chemistry. Physics teachers in suburban and lower need schools were more likely to have primary certifications when compared to teachers in urban, rural, and high need schools. Physics teachers in AP and college courses were more likely to hold primary certifications compared to those teaching college preparatory and other courses (Table 2).

Table 2. *Primary Certification of Physics Teachers by Locale, Socioeconomic Status, and Course*

Teachers with Primary Certification		821 (59%)
Number of Teachers by Locale	*Rural*	133 (46%)
	Suburban	484 (66%)
	Urban	211 (57%)
Number of Teachers by Socioeconomic Status	*High need*	273 (51%)
	Average need	445 (61%)
	Low need	305 (68%)
Number of Teachers by Course	*College preparatory*	671 (59%)
	AP & College	288 (78%)
	Other	263 (65%)

Prevalence of physics access and course-taking. Data were collected about the physics course accessibility and teachers in terms of the locales of the schools, i.e., urban, rural, and suburban/town. Overall, 74% of high schools in the state offered physics, and this varied widely by locale (Table 3). Only 48% of urban schools offered at least one physics course.

Table 3. *Number of Public High Schools Offering Physics by Locale and Socioeconomic Status*

Locale	# Schools	# Schools Offering Physics	Physics Teachers (%)
Urban	516	249 (48%)	367 (26%)
Rural	282	257 (91%)	291 (21%)
Suburban	386	366 (95%)	729 (53%)
Total	1184	872 (74%)	1387

Data concerning physics teachers in each locale provided an indicator of the issue of accessibility of physics courses. The distribution of students and physics teachers varied across locales, with urban schools having 42% of the high school students enrolled in the state but only had 28% of the physics teachers, while suburban communities had 45% of the students with over 50% of the physics teachers.

Certification as a predictor of student performance in physics. In order to identify variables that predict student performance in physics, two multivariable regression models were generated with a subgroup of isolated physics teachers (n=500). This subgroup was chosen since physics scores could be directly ties to the teachers who taught the students. In the first model, the outcome was school-level percentage passing rate on the state physics exam, and the independent variables were socioeconomic status and whether physics teachers were in-field or out-of-field. In the second model, the outcome was school-level percentage passing rate on the state physics exam, and the independent variables were socioeconomic status and whether teachers possessed primary vs. secondary certification in physics.

Both predictors were significant in the first regression equation (F(2, 498)=44.701, p<.001); adjusted R^2 = 0.149, indicating a medium effect size. Physics performance decreased 16.4 percentage points for students from schools with high need socioeconomic status, and increased 8.0 percentage points in schools with certified physics teachers. The two independent variables added statistically to the prediction (p<.01).

One predictor, school-level socioeconomic status was significant in the second regression equation (F(2, 499)=38.408, p<.001); adjusted R^2 = 0.130, indicating a medium effect size.

Performance on the physics examination decreased 17.4 percentage points for students from schools with high need socioeconomic status. Socioeconomic status added statistically to the prediction, $p<.001$. Primary vs. secondary certification status was not significant in the multivariable model ($p=.354$).

IMPLICATIONS FOR TEACHING/LEARNING OF SCIENCE

The results from this case study present insights about out-of-field teaching on contextual patterns in physics teacher certification, access and course-taking in physics, and in student performance. Fewer physics teachers in high need schools were certified to teach physics than was the case in other schools. This is problematic considering the importance of domain specific knowledge in the development of science teaching expertise (Chi et al., 1982), particularly in light of chronic inequities in precollege physics education (Tesfaye & White, 2012). In terms of course access and enrollment in the physics, the present study shows that at the state level, physics was less accessible to students in urban communities than other communities. Concerns about inequitable access to physics in urban communities are reinforced when looking at the distribution of primary and secondary physics teachers in urban and non-urban communities – urban communities had considerably fewer certified teachers even though they had relatively large numbers of students.

An important consideration in analyzing teacher preparation and certification requirements is the relationship of such qualifications to student performance. The multivariable models in the present study included socioeconomic status with certification variables to examine their combined relationship with student achievement. When examining a subset of physics teachers, students of out-of-field teachers were outperformed by students of in-field teachers; however, whether certified teachers held primary or secondary licenses did not predict student performance. Clearly, having uncertified physics teachers is problematic and ineffective in terms of student performance. However, it would appear that

teachers holding secondary certification are just as effective in terms of performance in introductory high school physics courses.

CONTRIBUTION TO INTEREST OF NARST MEMBERS

This study examined out-of-field teaching issues specific to New York State. While confining the study to a single state and particular subject (physics) are clear limitations, it does provide an in-depth view of some of the issues faced by a single state regarding out-of-field teaching. Urban schools could adopt the policies and practices of the suburban and rural districts in seeking and hiring science teachers with multiple certifications. Secondary certified teachers can teach many science courses and would be as effective (as the evidence shows) as primary certified teachers given the level they would be teaching. However, this may not apply to Advanced Placement and college course teaching. Overall, this could be a much more effective practice than the present situation, where principals may resort to incidental teaching assignments to staff courses, inadvertently diminishing opportunity to engage in high quality science teaching and learning.

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